Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/IL05/000246

International filing date: 02 March 2005 (02.03.2005)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/548,865
Filing date: 02 March 2004 (02.03.2004)

Date of receipt at the International Bureau: 15 March 2005 (15.03.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

PCT/IL 2005/000246

02 MAR 2005

PA 1255281

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

December 03, 2004

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: ***60/548,865***
FILING DATE: ***March 02, 2004***

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

H. L. Jackson

H. L. JACKSON
Certifying Officer

13281 U.S.PTO

22154 U.S.PTO
60/548865
030204

PROVISIONAL APPLICATION COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(c).

PATENT **Docket Number: 1268-220PRO** Type a plus sign (+) inside this box ☐ +

➢ INVENTOR(s) / APPLICANT(s)

LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)
SPINAT	Eli		Tel Aviv, Israel

➢ TITLE OF THE INVENTION *(280 characters max)*

A PROCESS FOR EXTRUSION OF TUBES FROM METAL ALLOY BILLETS

➢ CORRESPONDENCE ADDRESS

LOWE HAUPTMAN GILMAN & BERNER, LLP
1700 Diagonal Road, Suite 310
Alexandria, Virginia 22314
Customer No. 22429

TELEPHONE CALLS TO: **Benjamin J. Hauptman**
(703) 684-1111

➢ ENCLOSED APPLICATION PARTS *(check all that apply)*

☒	Specification	*Number of pages:*	*8*	☒	Small Entity Established
☒	Drawings	*Number of sheets:*	*1*	☐	Other (specify):

➢ METHOD OF PAYMENT *(check one)*

☒ A Credit Card Payment Authorization is enclosed to cover the Provisional filing fees.

☒ The Commissioner is hereby authorized to charge filing fees and credit Deposit Account Number: *07-1337*

PROVISIONAL FILING FEE: **160.00 or 80.00**

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are:

☐ Additional inventors are being named on separately numbered sheets attached hereto.

Respectfully submitted,

LOWE HAUPTMAN GILMAN & BERNER, LLP 22429

Benjamin J. Hauptman
Registration No. 29,310

1700 Diagonal Road, Suite 310
Alexandria, Virginia 22314
(703) 684-1111 BJH/etp
(703) 518-5499 Facsimile
Date: March 2, 2004

A PROCESS FOR EXTRUSION OF TUBES FROM METAL ALLOY BILLETS

FIELD OF THE INVENTION

This invention relates to extrusion of tubes from metal alloy billets, specifically magnesium alloys, as well as structure components produced by this method.

BACKGROUND OF THE INVENTION

Extrusion is a process for the production of profiles and tubes. In the process, a round metal block called "*billet*" is placed into a die of a predetermined shape. In the process, a punch forces the billet thru the die, whereby large deformations can be achieved. Such large deformations result in reduction in cross-section diameter and an increase in overall length, and change in the shape of the cross section of the original billet.

Internal high pressure (IHP) forming of tubular specimen is a widely used technique in automotive industry to produce structure components, made of steel and aluminium, whereby the forming process is normally conducted at room temperature.

SUMMARY OF THE INVENTION

The present invention provides a process for the manufacture of tubes from metal alloy billets. The process comprises the steps of:

1. heating up the pre-made solid billet to a predetermined temperature, positioning the billet in a container in the extrusion press equipped with a centrally located internal piercing mandrel, and pushing the piercing mandrel through the billet with the required load at the end of the piercing, the tube is plastically deformed with an increase in length and,

2. Extruded at a predetermined speed of the pushing ram through a die, the metal flows through the annular gap between the mandrel and the die. The

outer geometry and the inner diameter of the tube are determined by the die and mandrel respectively.

3. The ratio between the cross section areas of the billet and the tube is defined as the "Extrusion Reduction Ratio"

said process is characterized in that:

(a) The predetermined billet temperature, of step 1, being in the range of 300 to 600°C,

(b) The extrusion speed, of step 2 being in the range of 5 to 45 mm/sec, and

(c) The extrusion reduction ratio of step 3 being in the range of 10:1 to 50:1.

In a preferred embodiment of the present invention, the metal alloy is magnesium.

By a preferred option, various physical parameters of the obtained shaped tube are measured such as: yield strength, tensile strength, elongation in both axial and circumferential directions of the tube. These measurements, taken either continuously, or periodically, (preferably when calibrating the process and the machines) are used to adjust the exact pre-determined temperature and pre-determined extrusion speed, within the above defined range, to obtain the desired physical parameters of the resulting tube. The adjustment may be made by a computerized or manual feed-back loop so that the parameters are fine-tuned in accordance with the resulting tubes.

The process of the present invention also comprises a subsequent internal high pressure forming process at elevated temperatures. Therefore, the tube/extrusion is sealed on both ends, and an internal pressure is built up. As pressure medium for the internal high pressure (IHP) forming process gas or liquid is used. The forming process is conducted in a temperature range of 200°C-500°C, whereby different temperature field are realized in the tooling in order to improve the formability of the tube/extrusion.

The invention further provides any shaped structure manufactured by the process disclosed herein. The use of the tubes of the present invention for the production of shaped structures has the benefit of producing shaped structures

which are better capable of sustaining the forming pressures and are principally produced undamaged, uncracked and capable of sustaining post-production pressures.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is based on the observation that high quality structures of magnesium may be prepared when certain parameters are employed in the extrusion process. This novel method removes the problems associated with other techniques used for the manufacture of same metal alloy based structures. Such problems may be inhomogeneity of the alloy structure, abrasiveness of the alloy, brittleness of the manufactured object, and difficulties in obtaining certain desired structures which could result in increased production costs.

In the process of the present invention, undesired deformations of the metal alloy are minimized. This results in a better and more efficient processing technique. In the process the billets are heated to temperatures ranging from 300 to 600°C and pressed in a container through a die, which is maintained at a similar temperature. The die, which has a predetermined size, determines the outer diameter of the manufactured tube. A centrally positioned mandrel determines the inner diameter of the tube. Thus, the annular space formed between the die and the centrally positioned mandrel determines the outer and inner dimensions of the hollow tube, which is processed. When force is applied on the billet by the press ram, - the extrusion process is conducted with the speed of the ram, namely at 5 to 45 mm/sec. The billet material is squeezed through the annular space between the die and mandrel at a higher speed determined by the extrusion reduction ratio, which has a value ranging from 10:1 to 50:1. The extrusion reduction ratio is the ratio of the cross sectional area of the pierced billet before extrusion to the cross sectional area of the tube after extrusion. Thus, a hollow tube with a certain predetermined dimensions is obtained.

The mandrel has two basic and important functions. First, it is used to pierce the billet in the container, thereby causing the entire billet to undergo a plastic

deformation with an increase in length. Second, after piercing, the mandrel is used to extrude the pierced billed through the annular gap between the mandrel and the die to form the tube.

It is to be understood that the billets used with the method of the present invention may be undrilled billets or predrilled billets having a hollow center.

The magnesium alloys, may be any one of commercially available alloys such as AZ31, AZ61, AZ80, ZM21 and the like. Preferably, the billets used with the invention of the present application are ZM 21 and AZ31 alloys.

It should be understood that the novel method of the present invention may also be used with other metal alloys such as aluminum, copper, precious metals and superconductors.

The hollow tube structures obtained by the novel process of the present invention may be further used to produce structurally defined elements of different sizes and structural complexity to be used in various fields and for various purposes. The extruded products may be optimized for further treatment such as hydroforming, by extruding them at a certain strain rate, temperature or press ratio, as required by the treatment conditions.

The term **"internal high pressure forming"** refers in the present invention to any process in which a metal billet is placed into a die or mould having a pre-required shape of the finished product. A pressurized medium, typically liquid or gas , is intruded internally of the tube to form it in a radial course, directed outwardly in order to take up the shape of determined by the die or mould.

To reduce the weight of structure component, ultra light weight materials, such as magnesium may be used.

Beside extruded magnesium alloys such as the AZ31 or ZM21 alloy products, tubes or profiles welded out of sheet metal may also be used. To form magnesium AZ31 tubes at elevated temperatures the following requirements should be fulfilled.

The tooling is dived into segments, or inserts, which can be heated separately. These inserts, which may be isolated from each other, are located in the

expansion zone and in the guided zone. By separating the various segments, different forming temperatures may be realized in the guiding and in the expansion zone, as shown in **Fig.1**.

The term "***tooling***" as used herein refers to the required set up to form magnesium tubes at elevated temperatures. **Fig.2** shows such a tooling. The tooling consists of an upper and a lower die, whereby the split plane is equal to the horizontal mid plane of the tube. The lower - die consists of two units, the clamping- and the forming- unit. The clamping unit ensures that the end of the tubes are kept seal during the IHP forming process, furthermore the pressure medium is supplied thru it. The clamping unit consists of the crossheads, the hydraulic cylinders, the sealing punches and the appropriate heating-, cooling- and. The tube is formed into the forming unit, whereby the forming unit consist of the body material, the insert for free expansion, the insert for the guided zone, and the appropriate cooling and heating devices. The inserts in the guided and the expansion zone are heated separately. The upper die only consists of a forming unit.

In the expansion zone a high forming temperature (300-400°C) is necessary to achieve high circumferential strains. In the guided zone a lower forming temperature (100-200°C) is required. This can be justified by the fact that with increasing forming temperature the flow stress decreases to lower values (about 40 N/mm^2 at 350 or 400°C depending on the alloy). Therefore, only small axial forces can be transferred to the expansion zone. If the temperature is lower, the flow stress of the material increases and more axial force can be transferred to the expansion zone. This is very beneficial if the process includes axial feeding, since therewith more material can be fed to the expansion zone. For the case of a free bulging process, the applied axial forces lead to a compressive state of stress in the wall of the tube, which leads to a higher formability (higher circumferential strains).

The Forming pressure depends on the tube material, the tube wall thickness, forming temperature and on the part's geometry. This means that the lower the temperature and the smaller the radius that has to be formed, the higher the forming pressure. A higher wall thickness leads to a higher forming pressure as well.

For a free bulging process at 350°C and 2.2 mm gauge, the forming pressure is about 40 bar. Depending on the alloy used and its production technique the forming pressure may also vary.

As a pressure medium, gas or special heat resistant fluids may be used. In one preferred embodiment, the pressure medium is a gas. In a specific embodiment, the gas is selected from inert gases. The term "***inert***" refers to gases, which do not react with any other material (solid, liquid or gas) with which they are in contact, under the conditions used in the process of the present invention, and which do not decompose or oxidize under these conditions. Preferred gases are also those which may be regenerated for further use. Such gases may for example be nitrogen and the noble gases. The benefit of using gas as a pressure medium, and specifically the preferred gases mentioned hereinbefore, is that these gases may be heated to high temperatures suitable for the magnesium forming (200°-500°C). At these temperatures a liquid medium typically used in the hydroforming process may undergo decomposition.

The strain rate influences the formability of the tube material. The higher the forming temperature is, the higher the influence of the strain rate on the formability. Thus, in one case the components are formed at a constant strain rate. Depending on process time, and necessary formability the strain rate may vary between $2x10^{-1}$ s^{-1} and $1x10^{-4}$ s^{-1}.

Previous heat treatment may also influence the initial structure of the tube material. The tubes may be annealed at temperatures between 200°C and 500°C. In one preferred case, the annealing temperature is between 250°C and 300°C. If the tubes are annealed at this preferred temperature range for a maximum of 6 hours, a uniform, fine-grained structure may be observed. A grain size between 10μm and 50μm can be realized. This fine-grained structure leads to an improved formability, especially at low strain rates (smaller then $2x10^{-1}$ s^{-1}).

The process described herein, and more specifically, the steps which involve hydroforming may additionally be followed by subsequent hydroforming

operations in order to deform or provide additional structural modifications to the final product.

Example: Extrusion parameters used in the preparation of tubes from Magnesium AZ31 alloy billet.

The chemical composition of the billet used (including trace elements and impurities) was as follows: 2.856% Al, 1.022% Zn, 0.329% Mn, 0.004% Fe, 0.038% Si, 0.001% Cu, and 0.001% Ni.

A continuous casting system was used with a flat die of 42 mm, moving mandrel of 38 mm and a container of 110 mm. The predrilled billet was 200 mm in length, 107 mm in diameter and with a drilled hole diameter of 38 mm.

The velocity of extrusion process (Ram speed) was 15 mm/s, with the billet preheated entry temperature of 297°C. The die was heated at 300°C. No lubrication was used in the process. The extrusion ratio was 29:1 with an overall force of 4.45 MN.

Example 2: IHP Process

For the subsequent following IHP forming process, the extruded tubes are annealed at 300°C for 6 h. Thereafter, the tubes are preheated to a forming temperature of 350°C. Then the IHP forming process is conducted at a temperature in the forming zone 350°C. In the guided zone temperature is 250°C. Axial force is applied by the hydraulic cylinders, which travel the sealing punches. Therewith, a compressive state of stress can be build up in the wall of the tube. As pressure medium for the IHP forming nitrogen gas is used, whereby the pressure vs. time path ensures a constant strain rate over the process time.

CLAIMS:

1. A process for the manufacture tubes or structure components from alloy billets, the process comprises the steps of:

    1. heating the billet to a predetermined temperature,
    2. positioning the billet in an extrusion press equipped with an internal piercing mandrel and maintained at a predetermined temperature, and
    3 pushing the piercing mandrel, at a pre-determined extrusion speed, through the billet thereby producing a tubular billet with a predetermined outer geometry and an inner diameter of predetermined size with a reduction of the cross-section diameter of the shaped tube as compared to that of the billet and an increased length;

said process is characterized in that:

(a)The predetermined billet temperature, of step 1, being in the range of 300 to 600°C,

(b) The extrusion speed, of step 2 being in the range of 5 to 45 mm/sec, and

(c) The extrusion reduction ratio of step 3 being in the range of 10:1 to 50:1.

2. The process of claim 1, further comprising the step of internal high pressure forming, whereby the forming temperatures are in the range of 200 to 500°C, a liquid or a gas is introduced into the tube under sufficient pressure, the tube expands and fills a pre-shaped mould cavity, at the end of which point the formed structure is quenched by water or cooled on air at room temperature.

3. A tube according to claims 1 or 2 wherein said tube is magnesium.

4. A tube structure manufactured by the process of the preceding claims.

5. A formed structure manufactured by the process of claims 2 or 3.

Fig. 1

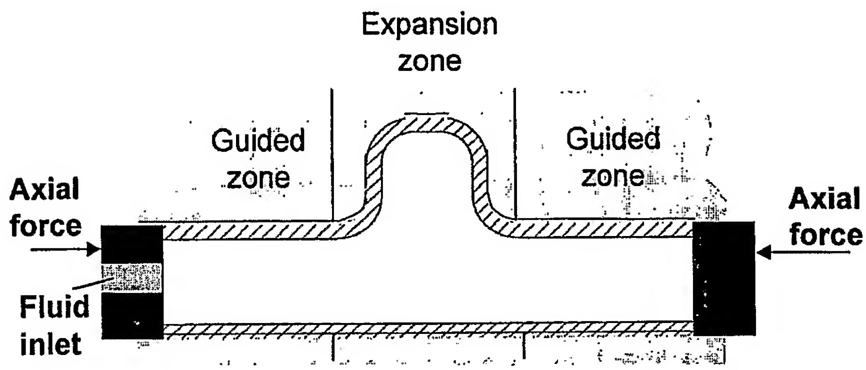
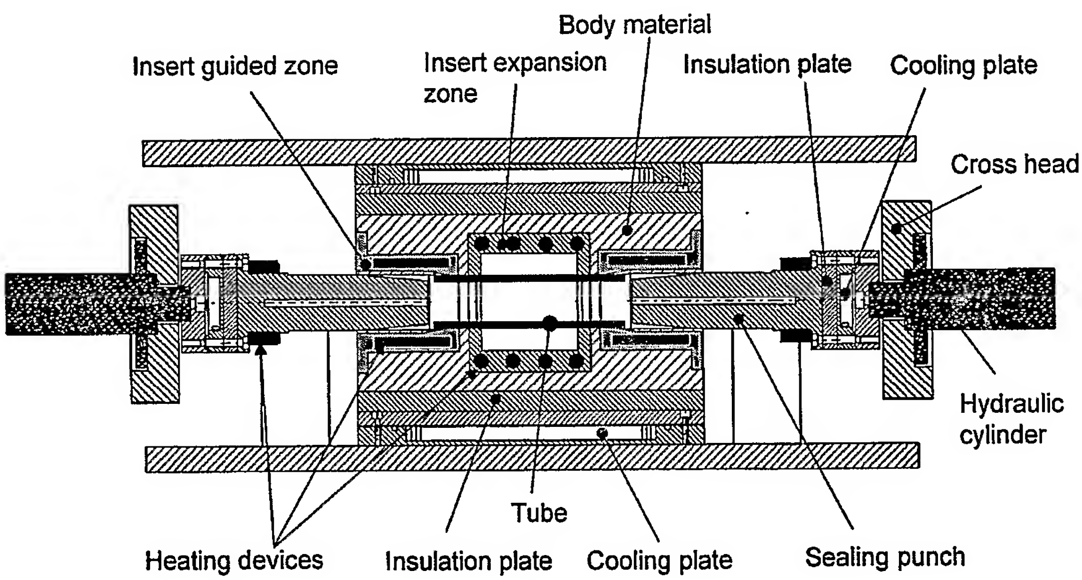

Expansion zone
Guided zone
Guided zone
Axial force
Axial force
Fluid inlet

Fig.2


Body material
Insert guided zone
Insert expansion zone
Insulation plate
Cooling plate
Cross head
Hydraulic cylinder
Tube
Heating devices
Insulation plate
Cooling plate
Sealing punch